

PATENT APPLICATION

of

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for a

TRANSMITTER FOR A VERY HIGH SPEED
DIGITAL SUBSCRIBER LINE

TRANSMITTER FOR A VERY HIGH SPEED DIGITAL SUBSCRIBER LINE

CROSS REFERENCE TO RELATED APPLICATIONS

5 This application is a continuation of U.S. application
number 09/471,757 filed on December 23, 1999, which in turn is
a continuation of U.S. application number 08/965,141 filed on
November 6, 1997, which in turn claims priority to U.S.
Provisional Application No. 60/052,128, filed on July 10,
1997, and to European application number 96402394.9 filed 8
10 Nov. 1996.

TECHNICAL FIELD

The present invention relates to a method to
transparently transport an incoming clock signal over a
network segment and to a transmitting unit and a receiving
15 unit equipped to perform this method.

BACKGROUND ART

As is well known in the art, such a method is to be used
for instance in telecommunication networks wherein a network
timing reference signal is to be transported over the network
20 but wherein data are transported over a network segment
synchronized to a timing reference signal internal for this
network segment. The network timing reference signal has to be
transmitted over this network segment although it may not be
used therein. Within a segment of an ATM (Asynchronous
25 Transfer Mode) network, data may for instance be transmitted
over a telephone line in accordance with the ADSL (Asymmetric
Digital Subscriber Line) specifications. The transmission of
data packed in ADSL frames over the telephone line between a
transmitting and a receiving modem is synchronized to the
30 modem clocks. Nevertheless, network layer specifications
require that the ATM network timing reference signal be
transparently transported over this ADSL network segment. From

the point of view of the network segment, the ATM network timing reference signal thus is an incoming clock signal which unaffectedly has to appear at the exit of the ADSL network segment, i.e. at the output of the receiving modem. This could
5 be done by sending the network timing reference signal over a separate transmission means or over the telephone line thereby using part of the transmission capacity of this line. Moreover, this way of transmitting the network timing reference signal implies a considerable complexity increase
10 for the transmitter and receiver.

DISCLOSURE OF THE INVENTION

An object of the present invention is therefore to realize the transmission of the timing reference signal in an efficient way, i.e. without a huge complexity increase of the
15 transmitter and receiver in the network segment over which the clock signal is to be transported.

According to the invention, this object is realized by a method to transparently transport an incoming clock signal with a well-known frequency over a network segment consisting
20 of a transmitting unit to an input of which the incoming clock signal is applied and to a clock input of which a transmit clock signal is applied by a transmitter clock, a transmission medium, and a receiving unit to a clock input of which a receive clock signal is applied by a receiver clock
25 synchronized with the transmitter clock, wherein the method includes the steps of measuring a phase difference value between the incoming clock signal and a reference signal obtained from the transmit clock signal; transmitting the phase difference value from the transmitting unit to the
30 receiving unit; and generating in the receiving unit an outgoing clock signal with a frequency equal to the well-known frequency, the outgoing clock signal having a phase difference with a second reference signal, similarly obtained from the

receive clock signal as the reference signal is obtained from the transmit clock signal, equal to the phase difference value.

5 The object is also realized by a transmitting unit to a first input of which data are applied and to a second input of which an incoming clock signal is applied, the transmitting unit including: embedding means, coupled between the first input and an output of the transmitting unit, and adapted to embed the data in data frames and to apply a data frame to the
10 output of the transmitting unit upon triggering by a reference signal derived from a transmit clock signal applied to a clock input of the transmitting unit by a transmit clock, wherein the transmitting unit further includes: phase measurement means to a first and a second input of which the incoming
15 clock signal and the reference signal are applied respectively, and which is adapted to measure a phase difference value between the incoming clock signal and the reference signal, and to apply the phase difference value to an output of the phase measurement means; and further that the
20 embedding means is provided with an additional input terminal connected to the output of the phase measurement means, the embedding means further being adapted to embed the phase difference value in a data frame.

25 The object is still further realized by a receiving unit to an input of which data frames are applied, the receiving unit including: de-embedding means with an input coupled to the input of the receiving unit, the de-embedding means being adapted to retrieve data to a first output of the receiving unit, and to retrieve a phase difference value out of a
30 reserved field of the data frames and to apply the phase difference value to a phase output of the de-embedding means, wherein the receiving unit further includes: generating means, to whose first input connected to the phase output the phase difference value is applied, and to whose second input a

second reference signal obtained from a receive clock signal applied to a clock input of the receiving unit by a receiver clock is applied, the generating means being adapted to generate an outgoing clock signal equal to the well-known
5 frequency and with a phase difference compared to the second reference signal equal to the phase difference value.

Indeed, since transmission over the network segment is synchronized to transmit the clock signal, and since both clock signals, the transmit clock signal and receive clock
10 signal, are synchronized, the receiving unit only has to become aware of the phase difference between the incoming clock signal and a reference signal synchronous to the transmit clock signal to be able to generate a copy of the incoming clock signal, provided that it also has a reference
15 signal similarly synchronous to the received clock signal. The reference signal may be obtained by frequency dividing the transmit clock signal. Obviously, a similar reference signal obtained by frequency dividing the receive clock signal then has to be used at the receiver's side in combination with the
20 measured phase difference value to generate the outgoing clock signal there. Determining the phase difference and using it in the receiver and generating a reference signal obviously requires less additional complexity in the transmitter and receiver than would be needed using known methods.

25 In a particular implementation of the present method wherein the additional required complexity is even more reduced, the reference signal equals the data frame clock signals.

30 In this way, the phase difference value is determined by measuring the time interval between the incoming clock signal and the data frame boundary each time a data frame is transmitted. The phase difference value is measured and transmitted once per data frame. If the data frame is

sufficiently large (e.g. an ADSL superframe with a length of 68 x 250 μ s (microseconds)), the additional overhead due to transmission of the phase difference value from transmitting to receiving unit is negligible. As will be seen later, the phase difference can easily be measured by means of a counter in this particular implementation.

An advantageous feature of this particular implementation is where the phase difference value is measured with a precision equal to one period of the transmit clock signal.

Indeed, as will be described in detail later on in the description, the just mentioned implementation with a counter can be realized so that the phase difference value is measured as an integer amount of transmit clock pulses. Since the transmit clock and the receive clock are synchronous, the phase difference to be realized in the receiving unit will also be an integer amount of receive clock pulses.

A further specific feature of the present method is that the phase difference value may be embedded in fields of the data frames.

In this way, no additional overhead is added to the data frames to transport the phase difference information. This technique is particularly recommended if in the network segment, data are transmitted packed in data frames wherein some fields are reserved for special use.

If the data are transmitted in the network segment in accordance with the Asymmetric Digital Subscriber Line (ADSL) specifications, the phase difference values may occupy fields reserved for so called fast bytes of Discrete Multi Tone symbols.

Indeed, an ADSL superframe contains several fast byte fields only a part of which are used for transporting operation channel related information. Consequently, the

remaining fast byte fields may be used to transport the phase difference values.

Another additional feature of the present method is where the phase difference value is transmitted only when it differs from the previously measured and transmitted phase difference value.

Hence overhead occupancy by phase difference values is further reduced by transmitting phase difference values only if they differ from a previous transmitted value. Since the receiver is aware of this previous transmitted value, it can continue generating the outgoing clock signal without precision decrease when it receives no new phase difference values for a certain time period.

In an alternative embodiment, not the phase difference itself but the deviation from the previous phase difference is transmitted. Again, the overhead can be reduced further by transmitting phase difference deviation values only if they differ from a previous transmittal value. This technique is especially advantageous in case of a fixed clock offset of the incoming clock signal relative to the reference signal synchronous to the transmit clock. In this case the phase difference deviations are (almost) constant and thus need not be transmitted.

BRIEF DESCRIPTION OF THE DRAWINGS

The above mentioned and other objects and features of the invention will become more apparent and the invention itself will be best understood by referring to the following description of an embodiment taken in conjunction with the accompanying drawing which shows a network segment with a transmitting unit TX and receiving unit RX performing an implementation of the method according to the present invention.

DETAILED DESCRIPTION OF THE INVENTION

The network segment of the figure consists of the cascade connection of a transmitter TX, a telephone line TL, and a receiver RX. The transmitter TX is provided with three input terminals; a data input DATA, a network clock input CLK2, and a transmit clock input CLK1. The transmitter TX further has one output terminal and is equipped with a data embedder EMBED and a phase measuring device PHASE. The receiver RX on the other hand has an input coupled to the telephone line TL, a receive clock input CLK1', a data output DATA', and a network clock output CLK2'. The receiver RX moreover includes a data de-embedder D-EMBED and a network clock generator GEN.

In the transmitter TX, the data embedder EMBED is coupled between the data input DATA and output terminal of the transmitter TX. The network clock input CLK2 serves as an input for the phase measuring device PHASE, and also the transmit clock input CLK1 is connected to an input of the phase measuring device PHASE. An output of the phase measuring device PHASE and an input of the data embedder EMBED are interconnected. The transmitter TX in the figure further contains an unlabeled star shaped device which may represent any kind of means which transforms the transmit clock signal CLK1 into a reference signal R. The reference signal R is thus nothing but a transformed clock signal CLK1, is synchronous with this clock signal CLK1 and is applied to inputs of the data embedder EMBED and phase measurement means PHASE respectively.

In the receiver RX, the data de-embedder is coupled between the input coupled to the telephone line TL and the data output DATA'. A phase output P of the de-embedder is connected to a first input of the network clock generator GEN, which has a second input interconnected with the receive clock input CLK1' and an output connected to the network clock

output CLK2' of the receiver RX. A similar star shaped,
unlabeled device is drawn in the receiver RX to represent any
kind of means, e.g. a sequence of frequency dividers, which
transforms the receive clock signal CLK1' into a reference
5 signal R' similar to the transformation in the transmitter TX.
The reference signal R' is applied to inputs of the data de-
embedder D-EMBED and network clock generator GEN respectively.

Two clocks, C1 and C1', in the figure represent the
transmit clock and receive clock respectively which generate
10 the transmit clock signal and receive clock signal
respectively. For evident reasons, their outputs are coupled
to the transmit clock input CLK1 of the transmitter TX and
receiver clock input CLK1' of the receiver RX respectively.

To illustrate the working of the drawn network segment
15 according to the present invention, it will be supposed in the
following paragraphs that ATM cells are applied to the data
input DATA of the transmitter TX to be transported over the
telephone line TL. These ATM cells are accompanied by a
network clock signal which is applied to the transmitter TX
20 via the network clock input CLK2. The network clock signal
typically is an 8 kHz signal, i.e. a signal with a pulse every
125 μ s. The transmitter TX and receiver RX can communicate
with each other and conform to the ADSL Specification. In
other words, the transmitter is an ADSL modem, which groups
25 incoming data DATA in DMT (Discrete Multi Tone) symbols and
embeds these DMT symbols in successive frames to constitute
with 68 successive frames a so called ADSL superframe FRAME.
The functional blocks of such an ADSL modem, and the structure
of DMT symbols, frames and superframes in ADSL are well known
30 by persons skilled in the art. The description thereof is not
relevant in view of the present invention. For more details
concerning these topics, reference is made to the approved
version of the ANSI (American National Standards Institute,

Inc.) Standard on ADSL, referred to as ANSI T1.413 and entitled "Network and Customer Installation Interfaces, Asymmetric Digital Subscriber Line (ADSL) Metallic Interface." The embedding of incoming data DATA in DMT symbols and ADSL superframes is realized by the embedder EMBED. Each time the reference signal R shows a pulse, the embedded EMBED applies an ADSL superframe via its output to the telephone line TL. The inverse operation is performed by the de-embedder D-EMBED in the receiver RX, triggered by the second reference signal R' which is obtained via similar frequency dividers from the receive clock signal CLK1'. The reference signal R is obtained from the transmit clock signal CLK1 by frequency division. The transmit clock signal CLK1, in this case the ADSL modem clock, has a frequency of 2.208 MHz.

The ATM network layer specifications require that the ATM network clock signal CLK2 of 8 kHz be transported throughout the whole network. The ADSL network segment comprising the transmitter TX, telephone line TL and receiver RX thus has to carry the ATM network clock signal from transmitter TX to receiver RX. For the ATM network, the ADSL network segment is a black box as a result of which it is not important how the network clock signal is transported between TX and RX. The next paragraph describes in a detailed way how the information necessary to enable the receiver RX to reconstitute the ATM network clock signal is determined in the transmitter TX. A subsequent paragraph explains how this information can be embedded in the ADSL superframes to be transferred to the receiver, and a third paragraph is dedicated to the processing in the receiver RX so as to generate the network clock signal from the receiver information.

Since the frequency of the ATM network clock signal is well-known (8 kHz), no information has to be transmitted between TX and RX with respect thereto. Dividing the modem clock signals (the transmit clock signal CLK1 in TX and

receive clock signal CLK1' in RX) of 2.208 MHz through 276
results in a new signal with a frequency of 8 kHz, i.e. the
ATM network clock frequency. The receiver RX thus only has to
be given phase information of the incoming ATM clock signal
5 CLK2 to be able to generate a perfect copy thereof at its
network clock output CLK2'. The phase measurement device PHASE
thereto determines the phase difference between the incoming
ATM network clock signal CLK2 and the reference signal R which
triggers the transmission of the ADSL superframes. In the
10 phase measurement means PHASE, a counter value is reset to
zero when the reference signal R shows a pulse. At that
moment, the embedder EMBED transmits an ADSL superframe. The
counter value is increased by one each time the transmit clock
signal CLK1 shows a pulse, and the counter value P is applied
15 via the output of the phase measurement means PHASE to the
embedder EMBED when the ATM network clock CLK2 shows a pulse.
Summarizing, the phase measurement device PHASE counts the
number of transmit clock pulses between the boundary of an
ADSL superframe and a network clock pulse. This number is a
20 measure of the phase difference P between CLK2 and R and will
be transmitted to the receiver RX.

The embedder EMBED has the task to incorporate the phase
difference P in the ADSL superframe. This superframe has a
length of 68 DMT symbols, i.e. $68 \times 250 \mu\text{s}$ in time. Each DMT
25 symbol contains a so called fast byte field. This field may be
used for special purposes, such as transport of operation
channel information, STM synchronization information, etc .
The already cited ADSL Standard Specification specifies how
the fast byte fields of the first two DMT symbols in an ADSL
superframe have to be used. The contents of other fast bytes,
30 i.e. those of DMT symbols 3 to 68, is not defined in the
Specification. Hence, one of these bytes may be used to
transport the phase difference P from transmitter TX to
receiver RX. Since one DMT symbol has a length of $250 \mu\text{s}$ and

the phase measurement means PHASE receives a pulse on CLK2 every 125 μ s, the value P is certainly determined at the end of the first DMT symbol of an ADSL superframe. As a consequence, it is no problem for the embedder EMBED to fill one of the fast bytes in DMT symbols 3 to 68 with the value P.

It is to be remarked that a smart embedder first checks whether the measured phase difference P differs from a previous measured value or not. To minimize use of bandwidth for transmission of phase difference values, the smart embedder writes the value of P in the fast byte field only when there is a difference.

At the receivers side, the de-embedder retrieves the value P from the fast byte field each time an ADSL superframe arrives, i.e. for each pulse of the reference signal R'. The phase difference value P then is applied to the generator GEN which constitutes the outgoing network clock signal CLK2'. From the receive clock signal CLK1' with a frequency of 2.208 MHz, an 8 kHz clock signal is created, again by a frequency division through 276. This 8 kHz clock signal needs to have a phase difference of P receive clock pulses with reference signal R' to be a perfect copy of the incoming TAM network clock signal CLK1. The generator GEN thus manipulates the 8 kHz signal obtained by frequency division of CLK1', e.g. by delaying the pulses so that the first pulse appears P clock periods of receive clock C1' after reference signal R' has shown a pulse.

It is noticed that the above embodiment is described in terms of functional blocks. The functional blocks, as is clear from the description of their working, contain no unknown components. Consequently, it is apparently obvious to a person skilled in the art of designing electronic circuits how to implement the different blocks EMBED, PHASE, D-EMBED and GEN,

given the above description of the functions performed by these blocks.

It should further be remarked that embedding the phase difference value P in fast byte locations is not a necessity when applying the clock transport method according to the present invention. Many alternative solutions, for instance using sync byte fields in ADSL superframes for phase difference value transport, can be thought of without inventive effort.

It should even be noted that the present invention is not limited to systems wherein the phase difference value P is transmitted embedded in frames, since it is obvious to any person skilled in the art, that the measured phase difference value may also be transmitted separated from the frames, e.g. in a time multiplexed or frequency multiplexed way with the frames, to enable the receiver to reconstruct the network clock signal CLK2.

Also a remark is that the phase measurement does not necessarily have to be executed each time a frame is transmitted from transmitter to receiver. The frequency of phase measurements is completely free. It is evident that there exists a trade-off between precision of the outgoing network clock and the amount of bandwidth resources used on the link. The more frequent phase measurements are done in the transmitter as more bandwidth is needed on the link between transmitter and receiver to transport the phase information, but the more precise a copy of the incoming network clock CLK2 can be generated in the receiver.

Another parameter which may influence the precision of the generated outgoing network clock is the used phase measurement technique. In view of this, it should be noted that an implementation wherein a counter is used which determines the phase difference P as an amount of transmit

clock periods is only one of the many variant techniques to measure the phase difference.

Furthermore, it has to be remarked that although the above described network segment is an ADSL segment receiving ATM cells at its data input and an accompanying ATM clock signal of 8 kHz, the present invention is not restricted thereto. It is clear to a person skilled in the art that minor modifications of the above described method allow it to be implemented in other networks, e.g. SDH (Synchronous Digital Hierarchy) networks, wherein data and network clock have to be transported over non ADSL network segments, e.g. VDSL (Very High Speed Digital Subscriber Line) segments, HFC (Hybrid Fiber Coax) segments, and so on.

A last remark is that, although the data symbols in the above described network segment are transported over a telephone line TL, the applicability of the present invention is not restricted by the transmission medium via which the data are transported. In particular, on any connection between two communicating units, TX and RX, e.g. a cable connection, an optical connection, a satellite connection, a radio link through the air, and so on, the present invention may be realized.

While the principles of the invention have been described above in connection with specific apparatus, it is to be clearly understood that this description is made only by way of example and not as a limitation on the scope of the invention.